R58-9

# DEHYDRATED FOODS*

M. C. Brockmann, Quartermaster Food and Container Institute for the Armed Forces, Chicago, Illinois.

As a matter of perspective, the development of agriculture is intimately linked with foods dried spontaneously in nature, especially the seeds of various grains (11). Spontaneously dried foods remain an important component of the human dietary. In addition, the feeding of grain and hay to meat and dairy animals represents an indirect consumption by man of naturally dried products. At this point it is relevant to call attention to the fact that there has been in recent years a marked expansion in facilities for drying grain artificially. In view of the probable extension of current harvesting practices, it is anticipated that facilities for drying grain artificially will continue to expand.

A more confused picture is presented by man's dateless efforts to utilize dehydration for the preservation of those components of his food supply which do not dry spontaneously. Almost all foods can be preserved by drying, generally without serious impairment of nutritional quality. A few dried products such as raisins, dates, and figs have remained important items of commerce for more than 2000 years. On the other hand, the historic procedures for the dehydration of foods usually are associated with adverse changes in texture, flavor, odor, or appearance. In many cases these changes are not apparent or are regarded as minor defects in a freshly prepared product. However, experience has demonstrated that adverse changes develop or become more

*Presented at the Symposium on Food Science and the Future, sponsored by the Division of Agricultural & Food Chemistry. 134th Annual Meeting of the American Chemical Society, Chicago, September 8, 1958.

intense as a function of both the time and the temperature of storage (19). The problem of deterioration during storage was brought into sharp focus as a result of World War II and has occupied a prominent position among the multiform activities which have been directed to dehydrated foods since this time.

As a result of recent development efforts, the way is now clear to produce 20 or more dehydrated products which compare favorably quality-wise with their frozen or canned counterparts, and which have been shown to retain acceptable quality after prolonged storage. In great measure the development of these satisfactory prototypes has been based on knowledge gained in the laboratory. For example, studies on changes occurring during drying and storage indicated that deterioration is frequently associated with the browning (Maillard) reaction. In the case of many fruits and vegetables treatment with $SO_2$ greatly reduced browning (19). With spray dried eggs deterioration is reduced by the removal of glucose prior to processing. Commodities of many different types exhibit a marked improvement in stability at low residual moisture levels. In cases in which the attainment of a low residual moisture is achieved only at the risk of increased damage during processing, observations have pointed to the feasibility of drying thinner slices or of using an in-package desiccant. The emphasis on lower residual moisture and on milder processing conditions has been reflected in the equipment used for dehydration. Noteworthy in this regard is the development of continuous, high vacuum equipment for the commercial production of dry orange juice and dry tomato solids (13) and the utilization of commercial freeze drying equipment for production of freeze dehydrated meat, poultry and fish (8).

There is general concurrence among technologists in the vegetable field that a thorough blanching is required to inactivate enzymes prior to dehydration (3). Such a blanching can be modified to yield quick cooking or precooked items (4). An outstanding example of precooking is seen in the case of dehydrated potatoes, which can be reconstituted in approximately one minute to yield high quality mashed potatoes, ready to eat. The review by Olson and Harrington (15) describing the tremendous experimental effort which ultimately led to the successful development of potato granules should be read by both food scientists and management. Food scientists will recognize the need for a diversified background in basic sciences. To management this review should serve as a case study in support of the conclusion that the path to the desired product is tortuous.

"Instant" mashed potatoes illustrate that dehydrated foods may have advantageous features independent of preservation. Other precooked dehydrated items such as sliced roast beef, ground beef, chicken, fish, shrimp, beans, rice, diced potatoes and a variety of soups have been developed. By combining individual dehydrated items with appropriate seasoning, a variety of combination dishes have been prepared such as chicken and rice, beef-potato hash, shrimp creole, chili and beans, and spaghetti and meat balls. These dishes are ready for serving within 10 or 15 minutes after addition of hot water. While many precooked foods have, as yet, not been prepared commercially in stable dehydrated form, it is well within the range of possibility that 80% or more of our common food items can become available as precooked dehydrated products. Under such circumstances, refrigeration would be unnecessary, hot and cold water would replace cooking facilities and equipment, no special skill would be required for meal preparation, actual working time would be only a few minutes per item, and, if disposable table service were used, home kitchens would be superfluous. Outside of the home, precooked dehydrated foods offer potential advantages for tourists, campers and the ever increasing population of lunch-carrying workers. On the commercial scene, the potential variety and ease of preparation suggest application for planes, trains, canteens, vending machines, and quick-serve eating establishments, especially those serving a large choice of foods at off hours.

The above advantages have counterparts in military feeding in zones having no refrigeration. In such zones in time of stress, canned goods have provided the only source of perishable products. Experience has demonstrated that many canned products, notably meats, become quite unacceptable after several weeks of continued use. By use of dehydrated foods, it is possible to bring into non-refrigerated areas a greater variety of perishable foods with characteristics more closely resembling fresh products. Moreover, use of dehydrated foods will reduce weight by 50 - 60%, and flexible packaging will contribute substantially to space economy. Also, unlike canned goods, dehydrated products require no precautions against freezing. Dishes from precooked dehydrated foods can be prepared quickly, without specially trained food service personnel, and without cooking equipment. While hot water would be required, this can be heated faster and more efficiently than wet food.

Properties such as reduced weight and volume, speed of preparation, and elimination of special personnel and equipment for preparation and serving are especially advantageous from the standpoints of increased mobility and dispersion. Also, reduced weight is a major advantage if air transport is to be employed. This advantage is greatly magnified if air drop is contemplated. In recognition of these advantageous features, the Armed Services support an active research and development program on dehydrated foods, and precooked, dehydrated meals.

Application of dehydration to achieve economy of weight and volume has been practiced in our civilian canned food industry for many years, especially with fluid products such as evaporated milk and tomato paste. These advantages have been extended to the frozen food industry with products such as concentrated frozen orange juice. More recently, in dehydrofrozen foods (18), dehydration combined with freezing is being extended to intact fruits and vegetables. In this process a fresh product, such as peas, is subjected to high velocity air dehydration for evaporation of the easily removable portion of the moisture. In the case of peas, weight reduction amounts to about 50%. The partially dehydrated product is then frozen. A substantial part of the drying cost is recovered by the decreased capacity needed for freezing. Also, contraction in volume permits economies in containers and in storage and shipping space. Most significant economy, however, is effected in transportation cost. Using peas as an example, 100 lbs. of fresh peas after dehydrofreezing are shipped as 51 lbs. The same amount of fresh frozen peas would represent a shipping weight of 102 lbs., and after canning 156 lbs. On a dollar basis, estimated costs for containers, storage, and transportation from California to Chicago are $2.35 for dehydrofrozen, $4.70 for frozen, and $5.60 for canned. Dehydrofreezing is obviously limited to products which can be dehydrated readily and without damage to the food as ultimately consumed. In the example at hand, during cooking, the peas take up water and return to normal without noticeable deterioration. An analogous picture is presented by dehydrocanning (17).

Up to this point speculation in regard to the future has represented an extrapolation of current trends in product development. Another and somewhat more imaginative insight into the future may be developed from more basic segments of current research which are intended to throw light on the nature of food products, the principles governing their behavior, and the fundamental aspects of their processing. Such studies are under the guidance of chemists, physicists, physiologists, geneticists, psychologists, representatives of several branches of engineering, and a number of applied scientists.

Few discussions in the field of food technology can omit recognition of the impact of raw materials on the behavior of the processed product. Experience has demonstrated that certain varieties of fruits and vegetables are more suitable for canning than other varieties. It is probable that the same picture will be forthcoming with dehydrated products. If an observable property contributes to the superiority of a product, it should be possible for a geneticist or a physiologist to enhance this property. Numerous reports have dealt with the relationship between the glycogen reserves in muscle at the time of slaughter and the subsequent changes during storage, freezing, or cooking. In view of the nature of the effects observed, it is probable that differences would also arise during dehydration, storage or rehydration as a result of the lactic acid developed from the glycogen. While the example at hand involved animal tissue, the effect of tissue reserves may play an analogous role in plants. Studies now in progress reveal that the state of the vacuole in leafy vegetables such as lettuce has a definite effect on behavior during both dehydration and reconstitution.

The identification and duplication of natural flavor components are largely in the hands of chemists. As pointed out at a recent symposium on food flavors (14), substantial progress has already been made and active programs embracing all classes of foods are currently underway. One of the most consistent criticisms of dehydrated products during the last war involved lack of flavor or presence of a straw-like flavor. While it may be impractical to prevent loss of flavor during dehydration, the possibility of restoring flavor is well within the realm of future expectation.

Changes ascribed to oxidative processes play a conspicuous part in the deterioration of dehydrated foods. Rancidity-type changes involving fat are recognized as important flavor defects. Evidence is accumulating which suggests that the stale flavor developed by roast beef is also related to rancidity. As will be mentioned later, the development of a tougher texture in certain products such as fish, is believed to be related to oxidative processes. In view of the research now underway on oxidative deterioration, there is little risk in predicting that a practical control of oxidative changes in dehydrated food will be forthcoming. Oxygen scavengers, either chemical or enzymic, together with improved facilities for replacing air with inert gas are expected to afford improved protection against changes induced by molecular oxygen during storage. The need for protection against oxygen during processing, especially at elevated temperature, is recognized in the case of several products.

Optimism surrounds the use of chemical additives to control oxidative changes. In certain cases, reducing agents such as ascorbic acid can afford some protection. Antioxidants of the types used in lard are effective in cases in which cell masses are disintegrated to the extent that a thorough distribution can be attained. In a somewhat similar vein, hope is seen for control of oxidation by the use of sequestering agents or other compounds which are presumed to interfere with the action of catalysts promoting oxidation. As in the case of antioxidants, the effectiveness of these compounds depends upon distribution. The recent report concerning the effectiveness of starch for preventing oxidation of carotene in dehydrated carrots may stimulate interest in still another area of antioxidant activity (12).

Texture is an elusive property of food which undoubtedly embraces a wide variety of connotations among different commodity specialists. We can look forward to attempts to purify the concept of food texture and to characterize it objectively. Whatever texture may be, it is an important property of food. After reconstitution and preparation for consumption, dehydrated foods are often observed to be tougher than their non-dehydrated counterparts. Storage frequently intensifies this defect. In the case of fish (2) this "toughness" problem has been attacked at both the microstructure level by histologists and at the molecular level by protein chemists. Chemical evidence suggests the development of cross linkages within the protein molecule even under the mildest conditions of dehydration. These changes, especially the cross linking, alter the hydration characteristics of the tissue, which in turn modifies its response to chewing. It is not improbable that uptake of oxygen such as has been reported for dry animal protein (8) may also contribute to toughening during storage. Should this oxidative process be connected with the development of cross-linkages through disulfide bonds, there is a fair possibility of preventing or reducing a considerable part of the toughness.

Porous products such as freeze dehydrated meat present still another possibility for texture modification. By incorporating a suitable proteolytic enzyme in the water used for rehydration, opportunity is presented for a uniform enzymic activity throughout the meat mass (20).

So-called bound water appears to occupy a key position with respect to physical property such as texture on one hand, and to processing behavior during dehydration or reconstitution on the other. The resistance of bound water to evaporation is of special concern to engineers who are developing processes and equipment for dehydration. This is evident from the frequency that various manifestations of bound water received attention at a conference dealing with the fundamental aspects of dehydration which was held in March of this year under the sponsorship of the Food Section of the Society of Chemical Industry. While the collected papers of this conference are not yet available, it is evident from the news summary (10) that bound water and moisture transfer during drying are the subjects of considerable research. For example, studies have been carried out on the rates of moisture migration in a homogeneous gel and in a system permeated by interconnecting capillaries. Such studies appear useful in analyzing the effect of case hardening on drying. A number of reports dealt with the phases observed in drying commodities such as wheat, fish and potatoes as characterized by rate curves. In the case of potatoes, Gorling (5) has analyzed drying on the basis of capillary transfer and diffusion of water vapor. Such data eventually will be translated by engineers into drying systems of improved performance. The role of engineering in the future of food dehydration is of such a magnitude as to constitute a suitable subject for another symposium.

There can be no question but that much of the success of recent dehydration effort can be attributed to milder process conditions. As a result there should be a movement in the direction of vacuum equipment. In air driers increased velocities may prove advantageous. For certain products sensitive to oxygen, it may be feasible to use an inert gas in a closed system. Notable advances have been achieved with continuous systems for the high vacuum flash drying or puff drying of essentially structureless products such as milk and juices. The possibility of extending such systems to process bite size pieces of intact tissue such as meat, vegetables and fruits, appears hopeful. The possibility of utilizing solvent systems for dehydration may prove feasible for certain products. Recent successful applications of freeze drying to foods, notably meats, have focused attention on the broad application of this process to food dehydration. This process combines low temperature with stability of tissue structure, and lack of mobility of soluble components during processing. It is virtually assured that this process will become more attractive as the result of improved technology and increased experience.

In considering the future of dehydrated foods, recognition must be given to the fact that drying can be, and often is, a relatively mild process. Lotus seeds preserved only by natural dehydration have been observed to germinate after more than 3000 years (1). Egg white and blood plasma can be spray dried--a relatively violent process--without denaturation. Independent investigations (9) (16) have shown that relatively little destruction of ATPase occurs during freeze drying, and that freeze dried muscle fibers have not lost their contractility.

The preceding comments on the future developments in dehydrated foods have in great measure been drawn from an extrapolation of current research and development. Military interest in food dehydration is based on preservation in combination with other collateral advantages. Civilian interest in dehydrated foods reflects the above mentioned collateral advantages.

Attention may be called to a statement carried in the published account (7) of a recent informal discussion meeting held at the Torry Research Station in England on the subject of the future of dehydrated food: "The conclusions drawn from this exchange of information were that there was great interest in the subject of the dehydration of food and confidence in its future as an expanding process inherently capable of standing alongside freezing and canning ...................."

(1) Briggs, Lyman J. and Weaver, Kenneth F. How old is it? National Geographic 114, 234-55 (1958)

(2) Cornell, J. J. Some aspects of the texture of dehydrated fish. J. Sci. Food Agr. 8, 526-37 (1957)

(3) Gooding, E. G. B. The scalding of vegetables before dehydration. Food Manuf. 31, 369-75 (1956)

(4) Gooding, E. G. B. Quick-cooking dehydrated vegetables. Food Manuf. 32, 513-5 (1957)

(5) Gorling, Paul. Untersuchungen zur Aufklarung des Trocknungsverhaltens pflanzlicher Stoffe. Diss. Munich (1956)

(6) Guilbot, Andre. Application de la Cryodessication aux Aliments. Bull. Soc. Sci. Hyg. Aliment. 45, 243-54 (1957).

(7) Hanson, S. W. F. Future work on dehydration. Chem. & Ind. 1958, 825-6.

(8) Harper, J. C. and Tappel, A. L. Freeze-drying of food products. Adv. Food Res. 7, 171-234 (1957).

(9) Hunt, Sheila M. V. and Matheson, N. A. Adenosine triphosphatase and contraction in dehydrated muscle fiber. Nature 181, 472-3 (1958).

The effects of dehydration on actomyosin in fish and beef muscle. Food Technol. 12, 410-6 (1958).

(10) Jason, A. C. Fundamental aspects of the dehydration of foodstuffs. Chem. & Ind. 1958, 821-5.

(11) Jensen, Lloyd B. Man's foods. The Garrard Press, Champaign (1953)

(12) Kuppuswamy, S. and McBean, D. McG. Effect of coating with starch and starch fractions on storage of dehydrated carrot. Food Technol. 11, 262-5 (1957).

(13) Legault, R. R. The dehydration of juices. Chapter 22, pp. 705-28. The chemistry and technology of fruit and vegetable juices production. (Ed. Donald K. Tressler and Maynard A. Joslyn) Ave. Publishing, New York (1954).

(14) National Academy of Sciences - National Research Council. Chemistry of natural food flavors. Quartermaster Food & Container Inst., Chicago (1957).

(15) Olson, R. L. and Harrington. W, C. Potato granules, development and technology of manufacture. Adv. Food Res. 6, 231-56 (1955).

(16) Partmann, W. and Berger. A. Zur Einwirkung von Rontgenstrahlen auf die ATP-Spaltung von Fischmuskulatur mit verschiedenem Wassergehalt. Z. Lebensm. -Untersuch u. -Forsch. 107, 327-40 (1958).

(17) Powers, M. J., Talburt, W. F., Jackson, R. and Lazar, M. E. Dehydrocanned apples. Food Technol. 12, 417-9 (1958).

(18) Ramage, W. D. Dehydrofreezing--A new processing method. Proceedings of Symposium: The future of food preservation. Midwest Research Institute, Kansas City, Apr. 2-3 (1957).

(19) Tressler, Donald K. New developments in the dehydration of fruits and vegetables. Food Technol. 10, 119-24 (1956).

(20) Wang, H., Weir, C. Edith, Birkner, Marion and Ginger, Betty. The influence of enzyme tenderizers on the structure and tenderness of beef. Proc. 9th Research Conf. Sponsored by the Council on Research of the Am. Meat Inst. 1957, 69-82.